Earth Radiation Budget Experiment (ERBE) S-8 Processed Archival Tape (PAT) Data in Native (NAT) Format Langley ASDC Data Set Document

Summary:

This document describes the Processed Archival Tape (PAT) and provides the user with the necessary information to use the Earth Radiation Budget Experiment (ERBE) data for scientific research studies. ERBE measurement level data are archived in two forms: the Raw Archival Tape (RAT) and the Processed Archival Tape (PAT). The RAT contains a comprehensive set of ERBE data including telemetry, ephemeris, and attitude data merged together sequentially by time. It also contains raw radiometric counts and raw and converted values and flags for spacecraft and instrument housekeeping data. Prior to launch, it became apparent that the RAT tape contained much data that is not directly useful in scientific studies and that many useful quantities like instantaneous radiometric estimates at the top of the atmosphere (TOA) were not being recorded. There was a wide data gap between raw counts on the RAT and monthly averaged output products. Thus, the PAT was created to contain the data most amenable to scientific studies. The PAT does not contain raw counts or housekeeping data, solar monitor data, or time and space averages. However, the PAT does contain all satellite and viewing geometry, and all scanner and nonscanner radiometric measurements in engineering units with flags defining their validity. The PAT also includes quantities such as scanner measurements corrected to flat spectral responses (unfiltered measurements), the scene identified for each scanner pixel, the estimate of flux at the TOA for each scanner pixel, and estimates of the flux from nonscanner measurements. Each PAT contains these ERBE data for a 24-hour period. The PAT was created with the user's interest in mind. This document should contain all the information needed to read the PATs and to interpret their contents.

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1. Data Set Overview:

Data Set Identification:

ERBE_S8_NAT: Earth Radiation Budget Experiment (ERBE) S-8
Processed Archival Tape (PAT) in Native (NAT) Format

Data Set Introduction:

The Processed Archival Tape (PAT) contains ERBE scanner and nonscanner radiometric measurements, their location and viewing angles at the top of the atmosphere, and estimates of the flux based on these measurements for one day and one satellite. All of the data are ordered chronologically and are divided into 16-second records.

Objective/Purpose:

The objectives of the ERBE are:

1. To determine, for a minimum of 1 year, the monthly average radiation budget on regional, zonal, and global scales.
2. To determine the equator-to-pole energy transport gradient.
3. To determine the average diurnal variation of the radiation budget on a regional and monthly scale.

Summary of Parameters:

The PAT (S-8) contains ERBE scanner and nonscanner radiometric measurements for one day and one satellite. Estimates of the flux at the TOA based on these measurements are also included. The 24-hour period is divided into 16-second intervals and each interval contains the following:

- Time in Julian day
- Spacecraft position and velocity
- Sun position
- Location of scanner FOV at TOA
- Scanner measurements in $Wm^{-2}sr^{-1}$ (total, shortwave, longwave)
- Nonscanner measurements in Wm^{-2} (total, shortwave)
- Scanner and nonscanner viewing angles at TOA
- Error flags on all measurements
- Unfiltered shortwave and longwave measurements for both instruments
- Estimate of flux at TOA from each scanner and nonscanner measurements
- Scene identification for each scanner measurement set

Discussion:

The goal of ERBE is to produce monthly averages of longwave and shortwave radiation parameters on the Earth at regional to global scales. Preflight mission analysis led to a three-spacecraft system to provide the geographic and temporal sampling required to meet this goal. Three nearly identical sets of instruments were built and launched on three separate spacecraft. These instruments differ principally in the spacecraft interface electronics and in the field-of-view limiters for the nonscanner instruments required because of differences in the spacecraft orbit altitudes.

The ERBS spacecraft was launched by Space Shuttle Challenger in October 1984 and was the first spacecraft to carry ERBE instruments into orbit. The ERBS was designed and built by Ball Aerospace Systems under contract to NASA Goddard Space Flight Center (GSFC), and ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. The ERBS carries the Stratospheric Aerosol and Gas Experiment II (SAGE II) in addition to the ERBE instruments. The Payload Operation and Control Center (POCC) at GSFC directs operations of the ERBS spacecraft and the ERBE and SAGE II instruments, employing both ground stations and the Tracking and Data Relay Satellite System (TDRSS) network. Spacecraft and instrument telemetry data are received at GSFC where the data are processed by the Information Processing Division that provides ERBE and SAGE II experiment data to the NASA Langley Research Center (LaRC).

The second and third spacecraft launched with ERBE instruments are Television Infrared Radiometer Orbiting Satellite (TIROS) N-class spacecraft, which are part of the NOAA operational meteorological satellite series. The NOAA-9 and NOAA-10 spacecraft were launched in December 1984 and September 1986, respectively. The NOAA spacecraft includes other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting. Both spacecraft are in nearly sun-synchronous orbits. The equator-crossing times (at launch) of the orbital nodes for the NOAA-9 and NOAA-10 orbits were 1420 UT (ascending) and 1930 UT (descending), respectively, where UT denotes universal time. The Satellite Operations and Control Center (SOCC) at the National Environmental Satellite and Data Information Service (NESDIS) operates the NOAA spacecraft. NOAA also provides decomputation processing of the telemetry data.

NASA tracks the ERBS spacecraft, and the North American Aerospace Defense Command (NORAD) tracks the NOAA spacecraft. The tracking data are provided to GSFC where orbit ephemeris data are calculated for all three spacecraft and provided to LaRC.

Related Data Sets:

SRB_Daily Surface Radiation Budget Daily Averages

2. Investigator(s):

Investigator(s) Name and Title:

Dr. Bruce R. Barkstrom
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NASA Langley Research Center

Title of Investigation:

Earth Radiation Budget Experiment (ERBE)

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3. Theory of Measurements:

The theory behind the measurements made to collect the ERBE data is non-trivial and well beyond the scope of this document. However, interested readers are referred to the following publications: NASA Reference Publication 1184, Vol I and II; NASA Technical Paper 2670; and Smith *et al* at (Reference 4).

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

All three sets of ERBE instruments were designed to collect data for one year but had a goal of two years. The nonscanner instruments continue to collect data for ERBS; however, the nonscanner instruments on-board NOAA-9 and NOAA-10 have been deactivated. Table 1 describes the nominal orbit parameters for each satellite at launch.

Table 1. Nominal Orbit Parameters for Each Satellite at Launch

Nominal Orbit Parameter	ERBS	NOAA-9	NOAA-10
Launch Date	October 5, 1984	December 12, 1984	September 17, 1986
Planned Duration	1 Year	1 Year	1 Year
Actual Duration Scanner	5-1/2 years (February 28, 1990)	3 years (January 20, 1987)	2-1/2 years (May 22, 1989)
Actual Duration Nonscanner	Operating	Over 12 years, deactivated April 3, 1997	Over 8 years, deactivated December, 1994
Orbit	Precessing	Sun-synchronous	Sun-synchronous
Semi-major Axis	6988 km	7248 km	7211 km
Mean Altitude	610 km	872 km	833 km
Inclination	57 deg	98 deg	98 deg
Nodal Period	98 minutes	102.08 minutes	101.2 minutes
Equator Crossing Time (at launch)	Variable	1430 Local Mean Solar Time, ascending	0730 Local Mean Solar Time, descending

Source/Platform:

The ERBE instruments are on the ERBS, NOAA-9, and NOAA-10 satellites.

Source/Platform Mission Objectives:

ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. ERBS carries Stratospheric Aerosol and Gas Experiment II (SAGE II) instruments in addition to the ERBE instruments. The NOAA spacecraft include other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-ResolutionInfrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting.

Key Variables:

A complete list of the measured parameters is found in Table 2.

Table 2. ERBS, NOAA-9, and NOAA-10 ERBE Detector Characteristics

	CHANNEL	WAVELENGTH LIMITS (microns)	MEASUREMENT
Nonscanner Fixed Wide field of view	1	0.2-50.0	Total Radiance
	2	0.2 - 5.0	Shortwave Reflected
Nonscanner Fixed Medium field-of-view	3	0.2 - 50.0	Total Radiance
	4	0.2 - 5.0	Shortwave Reflected
Fixed Solar Monitor	5	0.2 - 50.0	Total Irradiance
Scanner Narrow field-of-view	1	0.2 - 50.0	Total Radiance
	2	0.2 - 45.0	Shortwave Reflected
	3	5.0 - 50.0	Longwave Emitted

Principles of Operation:

ERBE is a multisatellite system designed to measure the Earth's radiation budget. The ERBE instruments fly on a mid-inclination NASA satellite (Earth Radiation Budget Satellite (ERBS)) and two two-synchronous National Oceanic and Atmospheric Administration (NOAA) satellites (NOAA-9 and NOAA-10). Each satellite carries both a scanner and a nonscanner instrument package.

The scanner instrument package contains three detectors to measure shortwave (0.2 to 5 microns), longwave (5 to 200 microns) and total waveband radiation (.2 to 200 microns) (Reference 2). Each detector scans the Earth perpendicular to the satellite groundtrack from horizon-to-horizon. The detectors are thermistors which use space views on every scan as a reference point to guard against drift. They are located at the focal point of an f/1.84 Cassegrain telescope, whose aluminum-coated mirrors have been overcoated to enhance ultraviolet reflectivity. The total channel has no filter and so absorbs all wavelengths. The shortwave channel has a fused silica filter which transmits only shortwave radiation. The longwave channel has a multilayer filter on a diamond substrate to reject shortwave energy and accept longwave. To enhance the spectral flatness of the detectors, each thermistor chip is coated with a thin layer of black paint. The instantaneous field-of-view (FOV) of each channel is hexagonal, with an angular size of 3 degrees by 4.5 degrees; the longer dimension being along the satellite groundtrack.

The nonscanner instrument package contains four Earth-viewing channels and a solar monitor (Reference 3). The Earth-viewing channels have two spatial resolutions: a horizon-to-horizon view of the Earth, and a field-of-view limited to about 1000 km in diameter. The former are called the wide field-of-view (WFOV) and the latter the medium field-of-view (MFOV) channels. For each of the two fields of view, there is a total spectral channel which is sensitive to all wavelengths and a shortwave channel which uses a high purity, fused silica filter dome to transmit only the shortwave radiation from 0.2 to 5 microns. The solar monitor is a direct descendant of the Solar Maximum Mission's Activity Cavity Radiometer Irradiance Monitor detector. Because of the concern for spectral flatness and high accuracy, all five of the channels on the nonscanner package are active cavity radiometers.

Sensor/Instrument Measurement Geometry:

The nonscanner elevation beams can be rotated to any of three positions: launch/stow/internal calibration position (180 degrees), solar calibration position (78 degrees), and Earth-viewing (nadir) position (0 degrees). The MFOV detectors are designed to include approximately an Earth view of 10 degrees within the unencumbered field of view (FOV).

The scanner can rotate in azimuth between 0 degrees and 180 degrees with an accuracy of 0.075 degrees. The normal scan mode is cross-track. The effective FOV of the scanner is 3 degrees.

Manufacturer of Sensor/Instrument:

The ERBE instruments were developed by TRW, Inc.

Calibration:

Specifications:

Specifications are currently unavailable.

Tolerance:

The tolerance is 1 percent for the total channel and 2 percent for the shortave channel.

Frequency of Calibration:

For the scanner instruments, in-flight calibrations were accomplished every scan, as well as on a bi-weekly basis. In-flight calibrations of the nonscanners were normally performed on a bi-weekly basis.

Other Calibration Information:

The ERBE instruments were developed by TRW, Inc. Laboratory calibrations of the ERBE nonscanner and solar monitor instruments were completed in the TRW calibration facility at Redondo Beach, California in 1984. The fundamental standards used for the ERBE instruments were the International Pressure and Temperature Standard of 1968 (IPTS-68) and the World Radiation Reference (WRR). The TRW master reference blackbody (MRBB) was calibrated using these, and the MRBB was subsequently used to transfer the calibrations to the internal blackbody (IBB) and to the shortwave channels via an integrating sphere. The results of the calibrations were reported in detail in TRW calibration documents.

In-flight calibrations are performed in order to maintain the accuracy of radiometric measurements by accounting for internal instrument component parametric changes brought about by the spacecraft's environmental variables. In-flight calibrations of the nonscanners were normally performed on a bi-weekly basis. These included internal calibrations, space looks, and solar calibrations. Internal calibrations consist of cycling of IBB temperatures (total sensors) and shortwave internal calibration source (SWICS) voltages. Space looks consist of observations of "cold" space, both before and after solar calibrations. Solar calibrations consist of measurements made while the solar disc is within the instrument's field-of-view.

On days when internal calibrations are performed, shortwave offsets are independently determined in four ways:

1. The preferred offsets are determined by using the aggregate of all earth-viewing data taken when the solar zenith angle is greater than 123 degrees, and assuming that the shortwave radiance is zero. Because of the solar zenith angle requirement, it is not always possible to use this method.
2. The second choice offsets are determined by using the data acquired during the internal calibration period, with the SWICS-off. Again it is presumed that the shortwave radiance is zero.
3. The third choice offsets are determined using data acquired during the so-called "B-soak" period which occurs before every internal calibration sequence is begun. During this period, all of the sensors are exposed to their respective calibration sources, but all power to the sources is off.
4. The fourth choice offsets are determined from the (approximately 30) samples of "cold" space which occur between the solar disk observation and the re-capture of the earth disk.

In cases where the first option is not viable, the second option is used, along with a linearly-fitted delta based upon the historical differences between method 1 and method 2. The offsets determined using options 3 and 4 have never been used in production processing.

5. Data Acquisition Methods:

The ERBE nonscanner instrument consists of four Earth-viewing detectors and one solar monitor detector located on the head assembly. The four Earth-viewing detectors are unchopped active cavity radiometers (ACR), whereas the solar monitor is an unfiltered chopped ACR designed to measure direct solar radiation for calibrating the Earth-viewing detectors. Two of these detectors have wide field-of-view (WFOV) apertures allowing the detectors to view the entire disk of the Earth; the other two detectors have medium field-of-view (MFOV) apertures allowing the detectors to view an area about 1000 km in diameter. Two of the Earth-viewing detectors, one WFOV and one MFOV, and the solar monitor detector measure total radiation, whereas the other two Earth-viewing detectors measure shortwave radiation. The total radiation detectors are unfiltered, and the shortwave spectral bands are achieved by use of fused silica dome filters placed over the detectors.

The nonscanner instrument microprocessor processes and executes ground-commanded and stored commands to direct and control the instrument operations. The instrument can operate in several modes so that radiation measurements can be made over a wide range of operational conditions. The instrument can operate at azimuth angles between 0 and 180 degrees, and at fixed elevation beam positions of 0 (nadir), 78 (solar ports), and 180 (stow or internal calibration position) degrees. Normal Earth-viewing operation is at the nadir elevation position and at an azimuth position of 180 degrees for NOAA-10, 170 degrees for NOAA-9, and 0 degrees for ERBS. The ERBE nonscanner instrument output consists of a complete cycle of radiometric and housekeeping measurements every 16 seconds. There are 20 radiometric measurements every 16 seconds, while the frequency of housekeeping measurements is either 1, 2, or 4 measurements per 16 seconds, depending on the type of measurement.

Telemetry data from the ERBE instruments on the NOAA-9 and NOAA-10 spacecraft are transmitted to Control and Data Acquisition (CDA) ground stations at Gilmore Creek, Alaska, and Wallops Island, Virginia that relay the data through a geostationary communications satellite to the SOCC at NESDIS in Suitland, Maryland. NOAA provides decommutation processing of the telemetry data and provides the data to LaRC. During portions of the ERBE mission, telemetry data from the NOAA spacecraft were transmitted to GSFC for decommutation processing and delivery to LaRC. Telemetry and tracking data from the ERBE instrument on ERBS are transmitted to the NASA ground terminal at White Sands, New Mexico through the Tracking and Data Relay Satellite System (TDRSS). The data are transmitted from the ground terminal to the NASA communications center at GSFC, where the data are processed by the Information Processing Division (IPD) that provides ERBE telemetry data to LaRC.

6. Observations:

Data Notes:

Data notes are currently unavailable.

Field Notes:

Field notes are currently unavailable.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

The spatial coverage differs with the channel and the spacecraft, as described below.

WFOV Instruments: these two fixed detectors continuously view the earth disc (plus a small ring of space). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitudes for ERBS which precesses approximately 3.95 degrees west per day.

MFOV Instruments: these two fixed detectors continuously view an area about 1000 km in diameter (nominally, a 5 degree earth central angle at the top of the Earth atmosphere, TOA). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitude for ERBS.

Scanner Instruments: these three scanning instruments continuously view small areas over the entire Earth. The cross-track scan FOV is approximately 40 km at nadir, and there is a 35 FOV overlap at nadir for ERBS between scans.

The ERBE instruments on board the NOAA-9 and NOAA-10 satellites provide global spatial coverage, while the scanner instruments on board the ERBS provides coverage between 67.5 degrees north and south latitude and the nonscanner instruments on board the ERBS provide coverage between 60 degrees north and south latitude.

Spatial Coverage Map:

Though a map is not available, the limits of coverage are discussed in the Spatial Coverage Section.

Spatial Resolution:

The spatial resolution differs with the four types of instruments and the two types of spacecraft (ERBS and NOAA). The WFOV instruments have 136-degree FOV on ERBS and 126-degree FOV on the NOAA satellites. The MFOV instruments have footprints of approximately 5 geocentric degree radius or 1000 km at the TOA. The scanner instruments have an instantaneous hexagonal FOV with an angular size of 3 x 4.5 degree, which is equivalent to a 31 x 47 km footprint at nadir for ERBS and 44 x 65 km for NOAA. The solar instrument has an unencumbered FOV which observes the entire solar disk.

Gridded products of the scanner data are available in 2.5 x 2.5 degree resolutions. S-4 and S-4G scanner data are also available as 5 x 5 degree and 10 x 10 degree nested grids. The 5 x 5 degree resolution and 10 x 10 degree nested grids are available for numerical filter nonscanner data, and the 10 x 10 degree resolution is available for the shape factor nonscanner data on the S-4 output product.

Projection:

Gridding is an equal-angle projection of 2.5 x 2.5 degree (NFOV, 10368 bins), 5.0 x 5.0 degree (MFOV, 2592 bins), and 10.0 x 10.0 degree

(WFOV, 648 bins).

Grid Description:

Binning of the data is based on an equal-angle grid of 2.5 x 2.5 degree (NFOV, 10368 bins), 5.0 x 5.0 degree (MFOV, 2592 bins), and 10.0 x 10.0 degree (WFOV, 648 bins). In each resolution, the bin number 1 is found at 90 degree N, 180 degree W with the bin number increasing in an easterly direction.

Temporal Characteristics:

Temporal Coverage:

Instruments on the three satellites (ERBS, NOAA-9, and NOAA-10) began acquiring Earth viewing data in November 1984, February 1985, and October 1986, respectively. All of the scanner instruments outlived their life expectancy of one year. The NOAA-9 scanner ceased operations on January 20, 1987 and the NOAA-10 scanner on May 22, 1989. The ERBS scanner ceased operations on February 28, 1990. All of the Earth-viewing nonscanner instruments collect measurements continuously except during calibrations. The solar instrument collects about 20 minutes of usable data during bi-weekly solar calibration periods.

Temporal Coverage Map:

A map is not available.

Temporal Resolution:

Each data granule consists of one day's worth of data that were collected by instruments from one of the three satellites (ERBS, NOAA-9, NOAA-10).

Data Characteristics:

Parameter/Variable:

The PAT contains ERBE scanner and nonscanner data for one day and one satellite. If all three satellites are operational on the same day, three separate PATs are required for a full set of ERBE data. The data period starts at Greenwich midnight (zero UT) and continues for 24 hours. This period is divided into 16-second intervals so that a PAT contains 5400 data records. If, however, there are periods of no data, or data dropout, the actual number of data records on a PAT will be less than 5400. As long as there is one valid scanner or nonscanner measurement within a 16-second interval, a full data record is output and the invalid data flagged accordingly. Each data record contains 3630 quantities that include satellite and viewing geometry, scanner and nonscanner radiometric measurements, and estimate of the radiant exitance at the top of the atmosphere. These quantities are offset and scaled by:

Integer Scaled Quantity = (Real Quantity + Offset) x (Scale Factor)

and packed into 54720 bits which comprise one PAT record.

Variable Description/Definition:

Table 3 describes each item in a PAT data record. The first column is a data item index. The parameter description and units are listed for each item, followed by a scale factor column and an offset column. The time interval columns list the number of seconds between each value of a given item. The next column lists the number of data item values in the record.

Scanner-related items appear in sets of 62 scan points for each of four scans. The final columns list the number of bits in each data item, the total bits for each item in the record, and the cumulative total of bits for all items in the record.

Table 3. Processed Archival Tape Format

Record Index	Parameter	Units	Scale Factor*	Offset*	Time Interval (Sec)	No. of Values/ 16-Sec.	No. of Bits/ Value	Total Bits/ 16-Sec.	Cum. Total Bits
1	Julian date	day	1	0	16.	1	32	32	32
2	Julian time	day	10^9	0	16.	1	32	32	64
3	Earth-sun distance	AU	10^9	0	16.	1	32	32	96
4	S/C position, x	m	1	0	16.	2	32	64	160
6	S/C position, y	m	1	0	16.	2	32	64	224

8	S/C position, z	m	1	0	16.	2	32	64	288
10	S/C velocity, x-axis	m sec^{-1}	1	0	16.	2	32	64	352
12	S/C velocity, y-axis	m sec^{-1}	1	0	16.	2	32	64	416
14	S/C velocity, z-axis	m sec^{-1}	1	0	16.	2	32	64	480
16	S/C Nadir, colatitude	deg	100	0	16.	2	16	32	512
18	S/C Nadir, Longitude	deg	100	-180	16.	2	16	32	544
20	Sun Position, Colatitude	deg	100	0	16.	1	16	16	560
21	Sun Position, Longitude	deg	100	-180	16.	1	16	16	576
22	Orbit Number	---	1	0	16.	1	16	16	592
23	Scanner, FOV, Colatitude	deg	100	0	0.033	62x4	16	3968	4560
271	Scanner, FOV, Longitude	deg	100	-180	0.033	62x4	16	3968	8528
519	Nonscanner, FOV, Colatitude	deg	100	0	0.8	20	16	320	8848
539	Nonscanner, FOV, Longitude	deg	100	-180	0.8	20	16	320	9168
559	Scanner, Radiometric, Total	$Wm^{-2}sr^{-1}$	10	0	0.033	62x4	16	3968	13136
807	Scanner, Radiometric, SW	$Wm^{-2}sr^{-1}$	10	0	0.033	62x4	16	3968	17104
1055	Scanner, Radiometric, LW	$Wm^{-2}sr^{-1}$	10	0	0.033	62x4	16	3968	21072
1303	WFOV, Radiometric, Total	Wm^{-2}	10	0	0.8	20	16	320	21392
1323	WFOV, Radiometric, SW	Wm^{-2}	10	0	0.8	20	16	320	21712
1343	MFOV, Radiometric, Total	Wm^{-2}	10	0	0.8	20	16	320	22032
1363	MFOV, Radiometric, SW	Wm^{-2}	10	0	0.8	20	16	320	22352
1383	Scanner, FOV, Zenith, Viewing	deg	100	0	0.033	62x4	16	3968	26320
1631	Scanner, FOV, Zenith, Sun	deg	100	0	0.033	62x4	16	3968	30228
1879	Scanner, FOV, Rel. Azimuth	deg	100	-180	0.33	62x4	16	3968	34256

2127	Nonscanner, FOV, Zenith, Viewing	deg	100	0	16.	2	16	32	34288
2129	Nonscanner, FOV, Zenith, Sun	deg	100	0	16.	2	15	32	34320
2131	Nonscanner, FOV, Rel. Azimuth	deg	100	-180	16.	2	16	32	34352
2133	Spares	---	1	9	---	2	16	32	34348
2135	Flag Words, Scanner Operations	---	1	0	16.	2	16	32	34416
2137	Flag Words, Nonscanner Operations	---	1	0	16.	2	16	32	34448
2139	Flag Words, Scanner, Rad., Total	---	1	0	0.033	18	16	288	34736
2157	Flag Words, Scanner, Rad., SW	---	1	0	0.033	18	16	288	35024
2175	Flag Words, Scanner, Rad., LW	---	1	0	0.033	18	16	288	35312
2193	Flag Words, WFOV, Rad., Total	---	1	0	0.8	2	16	32	35344
2195	Flag Wrods, WFOV, Rad., SW	---	1	0	0.8	2	16	32	35376
2197	Flag Words, MFOV, Rad., Total	---	1	0	0.8	2	16	32	35408
2199	Flag Words, MFOV, Rad., SW	---	1	0	0.8	2	16	32	35440
2201	Flag Words, Scanner, FOV	---	1	0	0.033	18	16	288	35728
2219	Flag Words, Nonscanner, FOV	---	1	0	0.8	2	16	32	35760
2221	Scanner, Unfiltered, SW	$Wm^{-2}sr^{-1}$	10	0	0.033	62x4	16	3968	39728
2469	Scanner, Unfiltered, LW	$Wm^{-2}sr^{-1}$	10	0	0.033	62x4	16	3968	43696
2717	Scanner, TOA Est., SW	Wm^{-2}	10	0	0.033	62x4	16	3968	47664
2965	Scanner, TOA Est., LW	Wm^{-2}	10	0	0.033	62x4	16	3968	51632
3213	WFOV, Unfiltered, SW	Wm^{-2}	10	0	4.	4	16	64	51696
3217	WFOV, Unfiltered, LW	Wm^{-2}	10	0	4.	4	16	64	51760
3221	MFOV,	Wm^{-2}	10	0	4.	4	16	64	51824

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	Unfiltered, SW								
3225	MFOV, Unfiltered, LW	Wm^{-2}	10	0	4.	4	16	64	51888
3229	WFOV, TOA Est., NF, SW	Wm^{-2}	10	0	32.	1	16	16	51904
3230	WFOV, TOA Est., NF, LW	Wm^{-2}	10	0	32.	1	16	16	51920
3231	MFOV, TOA Est., NF, SW	Wm^{-2}	10	0	32.	1	16	16	51936
3232	MFOV, TOA Est., NF, LW	Wm^{-2}	10	0	32.	1	16	16	51952
3233	WFOV, TOA Est., SF, SW	Wm^{-2}	10	0	32.	1	16	16	51968
3234	WFOV, TOA Est., SF, LW	Wm^{-2}	10	0	32.	1	16	16	51984
3235	MFOV, TOA Est., SF, SW	Wm^{-2}	10	0	32.	1	16	16	52000
3236	MFOV, TOA Est., SF, LW	Wm^{-2}	10	0	32.	1	16	16	52016
3237	Spares	---	1	0	---	4	16	64	52080
3241	Scanner, FOV, Scene, ID	---	10	0	0.033	62x4	8	1984	54064
3489	Flag, Nonscanner, TOA Est.	---	1	0	16.	1	8	8	54072
3490	Spares	---	1	0	---	21	8	168	54240
3511	Flag, Nonscanner, WFOV	---	1	0	0.8	20	4	80	54320
3531	Flag, Nonscanner, MFOV	---	1	0	0.8	20	4	80	54400
3551	Spares	---	1	0	---	80	4	320	54720
* These are nominal values. The actual values used to scale the data are recorded in the third PAT file, records 1 and 2.									

The remainder of this section lists definitions for each data item. Each definition begins with PAT (INDEX) and the parameter name. This heading is followed by a brief description of the parameter. The range of possible values is denoted by brackets. Some definitions are followed by notes which list more detailed information about the data item.

PAT(1) - Julian Day. The Julian day is the whole part of the Julian date at the beginning of each 16-second PAT record (days). [2440000 - 2460000]

PAT(2) - Julian Time. The Julian time is the fractional part of the Julian date at the beginning of each 16-second PAT record (days). [0 - 1]

NOTE: A new day begins with a Julian time of 0.5 so that a full 24-hour PAT tape starts with a Julian time given by
0.5 <= Julian time < 0.5 + 16/86400. Likewise, the last time will be 0.5 - 16/86400 <= Julian time < 0.5. A Julian day number table with discussion is given in Appendix B of the ERBE S-8 User's Guide.

PAT(3)- Earth-Sun distance. This is the approximate Earth-sun distance during the PAT record in astronomical units (AU). [0.98 - 1.02]

This distance is updated every 60 seconds from ephemeris data.

PAT(4-5) - S/C position, x. These elements contain the x positions of the spacecraft at the beginning and end of the 16-second PAT record in the Earth equatorial-Greenwich coordinate system (m).

NOTE: The Earth equatorial-Greenwich coordinate system is an Earth-fixed, geocentric, rotating coordinate system with the x-axis in the equatorial plane through the Greenwich meridian, the y-axis lies in the equatorial plane 90 degrees to the east of the x-axis, and the z-axis is toward the North Pole.

The inertial position and velocity of the spacecraft is known every 60 seconds from ephemeris data. The ephemeris data nearest to the beginning record time is used to determine the Keplerian orbital elements which are evaluated at the desired record times. These inertial positions are then transformed into the rotating, Earth-fixed coordinate system at the appropriate time.

Since the spacecraft position and velocity are given at the beginning and end of the record, the end conditions from one record are the same as the beginning conditions of the next record.

PAT(6-7) - S/C position, y. These are the y positions of the spacecraft at the beginning and end of the 16-second PAT record in the Earth equatorial- Greenwich coordinate system (m). See PAT(4-5) NOTE.

PAT(8-9) - S/C position, z. These are the z positions of the spacecraft at the beginning and end of the 16-second PAT record in the Earth equatorial- Greenwich coordinate system (m). See PAT(4-5) NOTE.

PAT(10-11) - S/C velocity, x-axis. These are the inertial velocities of the spacecraft along the x-axis at the beginning and end of the 16-second PAT record in the Earth equatorial-Greenwich coordinate system (m/sec). See PAT(4-5) NOTE.

NOTE: The inertial velocity is determined from the Keplerian orbital elements and its three components are transformed into the rotating, Earth-fixed coordinate system. However, this inertial velocity is not adjusted to reflect the rotational velocity of the Earth-fixed coordinate system.

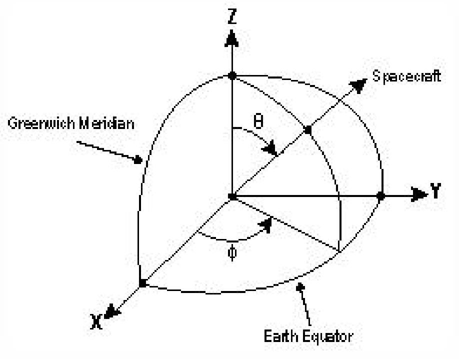
PAT(12-13) - S/C velocity, y-axis. These are the inertial velocities of the spacecraft along the y-axis at the beginning and end of the 16-second PAT record in the Earth equatorial-Greenwich coordinate system (m/sec). See PAT(4) and PAT(10) NOTES.

PAT(14-15) - S/C velocity, z-axis. These are the inertial velocities of the spacecraft along the z-axis at the beginning and end of the 16-second PAT record in the Earth equatorial-Greenwich coordinate system (m/sec). See PAT(4) and PAT(10) NOTES.

PAT(16-17) - S/C nadir, colatitude. These are the colatitudes of the spacecraft at the beginning and end of the 16-second PAT record in the Earth equatorial- Greenwich coordinate system (deg). [0 - 180]

NOTE: The colatitude and longitude of the spacecraft at the beginning of the PAT record are determined as follows:

The position of the spacecraft is



x = PAT(4)
y = PAT(6)
z = PAT(8)

and the radius is

$r = [x^2 + y^2 + z^2]^{1/2}$

so that the colatitude is

$$\theta = \cos^{-1}\frac{z}{r} \qquad 0° <= \theta <= 180°$$

The projection of the radius on the equatorial plane is

$r^{eq} = [x^2 + y^2]^{1/2}$

so that the longitude is

$$\cos\phi = \frac{x}{r_{eq}}$$

$$\sin\phi = \frac{y}{r_{eq}}$$

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$$\phi = \tan^{-1} \frac{\sin \phi}{\cos \phi} \qquad 0° <= \theta <= 360°$$

PAT(18-19) - S/C nadir, longitude. These are the longitudes of the spacecraft at the beginning and end of the 16-second PAT record in the Earth equatorial- Greenwich coordinate system (deg). [0 - 360] See PAT(16) NOTE.

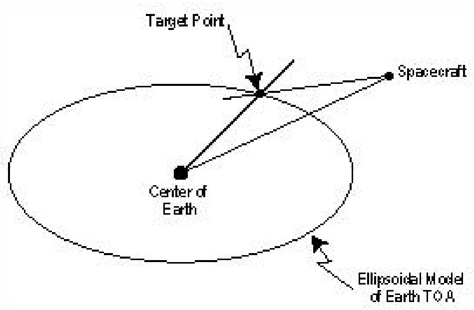
PAT(20) - Sun position, colatitude. This is the colatitude of the sun at the beginning of the PAT record in the Earth equatorial-Greenwich coordinate system (deg.). [0 - 180]

PAT(21) - Sun position, longitude. This is the longitude of the sun at the beginning of the PAT record in the Earth equatorial-Greenwich coordinate system (deg.). [0 - 360]

PAT(22) - Orbit number key. The orbit number is an index of the spacecraft revolutions about the Earth. It increases by 1 at the ascending node or when the spacecraft passes from the southern hemisphere to the northern hemisphere. It is a relative measure since orbit number 1 may not correspond to the first revolution about the Earth. The orbit number is from the orbital ephemeris data provided by Goddard Space Flight Center.

PAT(23-270) - Scanner, FOV, colatitude. This is the colatitude of the scanner target points in the Earth equatorial-Greenwich coordinate system (deg) [0 - 180].

NOTE 1: A target point is the point where the sensor's optical axis pierces an ellipsoidal TOA. See PAT(1383) NOTE.



NOTE 2: A scanner cycle is 4 seconds so that 4-cycles are recorded on each 16-second PAT record. Each 4-second cycle is divided into 120 time increments or 30 increments per second. The scanner views the Earth during increments 9 to 70. The geometry and radiometric measurements for each of these 62 increments are recorded on the PAT. If space is viewed during any of these increments, default values are recorded for the PAT parameters. There are various scanner notes. See PAT(2135).

PAT(271-518) - Scanner, FOV, longitude. This is the longitude of the scanner target points in the Earth equatorial-Greenwich coordinate system (deg) [0 - 360]. See PAT(23) NOTES.

PAT(519-538) - Nonscanner, FOV, colatitude. This is the colatitude of the nonscanner target points in the Earth equatorial-Greenwich coordinate system (deg) [0 - 180]. See PAT(23) NOTE 1.

NOTE: Nonscanner geometry and radiometric measurements are recorded on the PAT every 0.8 seconds so that there are 20 per 16-second PAT record.

PAT(539-558) - Nonscanner, FOV, longitude. This is the longitude of the nonscanner target points in the Earth equatorial-Greenwich coordinate system (deg) [0 - 360]. See PAT(23) NOTE 1 and PAT(519) NOTE.

PAT(559-806) - Scanner, radiometric, total. This is the scanner total channel filtered measurement at satellite altitude ($Wm^{-2}sr^{-1}$). See PAT(2139) and PAT(2201).

NOTE: A filtered scanner measurement is modeled as the integral over wavelength λ of the product of the actual spectral radiance L_λ incident on the instrument and the instrument channel spectral response S_λ , or

$$m_F^i = \int_0^\infty S_\lambda^i L_\lambda d_\lambda \qquad i = \text{total, shortwave, longwave}$$

These are the "raw" measurements as produced after count conversion. There are two independent flags that pertain to these measurements. The radiometric measurement is "good" or "bad" according to PAT(2139), and the FOV is "good" or "bad" according to PAT(2201). If the measurement does not exist, a default value is used as fill data.

PAT(807-1054) - Scanner, radiometric, shortwave. This is the scanner shortwave channel filtered measurement at satellite altitude and is dominated by the spectral radiance between 0 - 5 microns ($Wm^{-2}sr^{-1}$). See PAT(559) NOTE, PAT(2201), and PAT(2175).

PAT(1055-1302) - Scanner, radiometric, longwave. This is the scanner longwave channel filtered measurement at satellite altitude and is dominated by the spectral radiance greater than 5 microns ($Wm^{-2}sr^{-1}$). See PAT(559) NOTE, PAT(2201), and PAT(2175).

PAT(1303-1322) - WFOV, radiometric, total. This is the WFOV total channel filtered measurement at satellite altitude averaged over 4 seconds (Wm^{-2}). See PAT(2193) NOTE and PAT(2219).

NOTE: A filtered nonscanner measurement is modeled as a triple integral over wavelength and solid angle. The first integral is over the wavelength λ of the product of the actual spectral radiance L_λ incident on the instrument and the instrument channel spectral response S_λ. This filtered spectral radiance is then weighted by a flat plate cosine response, $\cos\zeta$, and integrated over the FOV, or

$$m_F^i = \int_{\xi=0}^{2\pi} \int_{\zeta=0}^{\zeta_b} \int_{\lambda=0}^{\infty} S_\lambda^i L_\lambda(\zeta,\xi) \cos\zeta \sin\zeta \, (d\lambda)\,(d\zeta)\,(d\xi)$$

i = total, shortwave, longwave

where ζ is the nadir or cone angle and ξ is the clock angle. The integration over the nadir angle is from 0 (straight down) to ζ_b which is the angle to the boundary of the FOV. These are the "raw" measurements as produced over count conversion. Because of the instrument characteristics, the 0.8 second measurements are averaged over four seconds. There are two independent flags that pertain to these measurements. The radiometric measurement is "good" or "bad" according to PAT(2193), and the FOV is "good" or "bad" according to PAT(2219).

PAT(1323-1342) - WFOV, radiometric, shortwave. This is the WFOV shortwave channel filtered measurement at satellite altitude averaged over 4 seconds and is dominated by the spectral radiance between 0 - 5 microns (Wm^{-2}). See PAT(1303) NOTE, PAT(2195), and PAT(2219).

PAT(1343-1362) - MFOV, radiometric, total. This is the MFOV total channel filtered measurement at satellite altitude averaged over 4 seconds (Wm^{-2}). See PAT(1303 NOTE, PAT(2197), and PAT(2219).

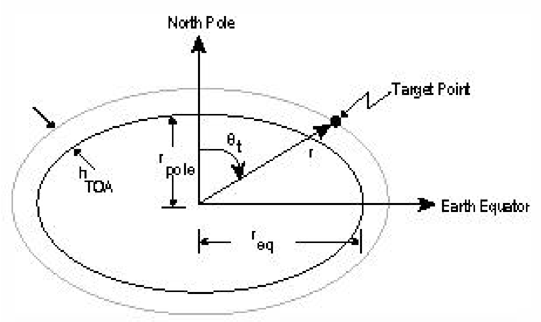
PAT(1363-1382) - MFOV, radiometric, shortwave. This is the MFOV shortwave channel filtered measurement at satellite altitude averaged over 4 seconds and is dominated by the spectral radiance between 0 - 5 microns (Wm^{-2}). See PAT(1303) NOTE, PAT(2199), and PAT(2219).

PAT(1383-1630) - Scanner, FOV, zenith, viewing. This is the zenith angle of the spacecraft at the scanner target point or the angle between the vector from the center of the Earth to the target point and a vector from the target point to the spacecraft (deg) [0 - 90]. See PAT(23).

NOTE: The three directional angles are determined as follows: The colatitude and longitude of the target point is

θ_t = PAT(23)
φ_t = PAT(271)

The ellipsoidal model of the Earth's TOA is symmetric about the Earth spin axis so that we have the following geometry:



where the physical constants are r^{eq} = 6378.160 Km, r^{pole} = 6356.775 Km, and h^{TOA} = 30 Km. The radius of the target point *r* is determined from

$$\left(\frac{r \sin\theta_t}{r_{eq} + h_{TOA}}\right)^2 + \left(\frac{r \cos\theta_t}{r_{pole} + h_{TOA}}\right)^2 = 1$$

so that the position of the target point is

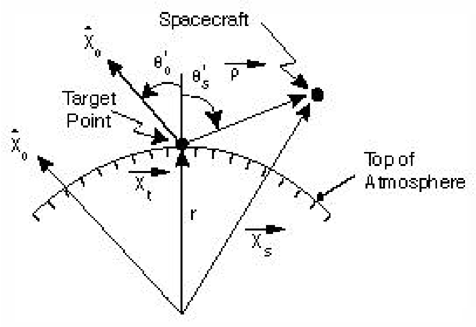
$x_t = r \sin\theta_t \cos\varphi_t$
$y_t = r \sin\theta_t \sin\varphi_t$
$z_t = r \cos\theta_t$

The position of the spacecraft is

x_s = PAT(4)
y_s = PAT(6)
z_s = PAT(8)

and the unit position of the sun is

θ_0 = PAT(20)
φ_0 = PAT(21)
$x_0 = \sin\theta_0 \cos\varphi_0$
$y_0 = \sin\theta_0 \cos\varphi_0$
$z_0 = \cos\theta_0$



In vector notation we have

$$\vec{\rho} = \vec{x}_s - \vec{x}_t$$

$$\theta'_s = \cos^{-1}\left(\frac{\vec{x}_t \cdot \vec{\rho}}{|\vec{x}_t|\,|\vec{\rho}|}\right) \qquad 0° \le \theta'_s \le 180°$$

$$\theta'_0 = \cos^{-1}\left(\frac{\vec{x}_t \cdot \vec{x}_0}{|\vec{x}_t|}\right) \qquad 0° \le \theta'_0 \le 180°$$

The azimuth of the spacecraft relative to the target-sun plane is given by

$$\vec{A} = \vec{x}_t \times \hat{x}_0$$
$$\vec{B} = \vec{x}_t \times \vec{x}_s$$

$$\cos\phi' = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}|\,|\vec{B}|}$$

$$\sin\phi' = \frac{\vec{B} \times \vec{A} \cdot \vec{x}_t}{|\vec{A}|\,|\vec{B}|\,|\vec{x}_t|}$$

$$\phi' = \tan^{-1}\frac{\sin\phi'}{\cos\phi'} \qquad 0° \le \phi' \le 360°$$

PAT(1631-1878) - Scanner, FOV, zenith, sun. This is the zenith angle of the sun at the scanner target point or the angle between the vector from the center of the Earth to the target point and a vector from the target point to the sun (deg) [0 - 180]. See PAT(1383) NOTE.

PAT(1879-2126) - Scanner, FOV, relative azimuth. This is the azimuth angle of the spacecraft at the scanner target point relative to the solar plane. The azimuth is measured clockwise in the local horizon plane so that the azimuth of the sun is always 180 degrees. If the target point is north of the sun on the same meridian, an azimuth of 90 degrees would imply the spacecraft is east of the target point (deg) [0 - 360]. See PAT(1383) NOTE.

PAT(2127-2128) - Nonscanner, FOV, zenith, viewing. This is the zenith angle of the spacecraft at the nonscanner target or the angle between a vector from the center of the Earth to the target point and a vector from the target point to the spacecraft. The zenith angle is given at the 1st and 20th nonscanner measurement point and is nominally zero (deg). [0 - 90}. See PAT(23), PAT(519), and PAT(1383) NOTES.

PAT(2129-2130) - Nonscanner, FOV, zenith, sun. This is the zenith angle of the sun at the nonscanner target point or the angle between a vector from the center of the Earth to the target point and a vector from the target point to the sun. The zenith angle is given at the 1st and

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20th nonscanner measurement point (deg). [0 - 180]. See PAT(23), PAT(519), and PAT(1383) NOTES.

PAT(2131-2132) - Nonscanner, FOV, relative azimuth. This is the azimuth of the spacecraft at the nonscanner target point relative to the solar plane. The azimuth is measured clockwise in the local horizontal plane so that the azimuth of the sun is always 180 degrees (deg). [0 - 360]. See PAT(23), PAT(519), PAT(1283), and PAT(1879) NOTES.

PAT(2133-2134) - Spares. These are spares and not used.

PAT(2135-2136) - Flag word, scanner operations. This is a record level flag and defines the scanner condition during the 16-second record. Each bit of this 2-word flag is defined in Table 4.

Table 4. PAT Flag Words, Scanner Operations

Bit Position (Right to Left)	Bit Value	Meaning
Word 1 (PAT(2135)):		
0	0	Instrument power in ON
	1	Instrument power in OFF
1-2	00	Calculating MAM and Earth-viewing vectors
	01	Calculating MAM-viewing vectors only
	10, 11	Not calculating viewing vectors
3	0	No telemetry data drop out
	1	Telemetry data drop out due to:
		a) Previous record missing;
		b) Scanner instrument disabled on previous record; or
		c) Scanner command echo bad on previous record
4-5	00	Elevation motor power ON
	01	Elevation motor power OFF
	10, 11	Elevation motor power undefined
6-7	00	Azimuth motor power ON
	01	Azimuth motor power OFF
	10, 11	Azimuth motor power undefined
8-9	00	First record since the end of a solar calibration
	01	First record since the end of an internal calibration
	10, 11	No calibration sequence ended in the previous record
10-11	00	Solar Calibration is in progress
	01	Solar calibration is not in progress
	10, 11	Status of solar calibration is undefined
12-13	00	Internal calibration is in progress
	01	Internal calibration is not in progress
	10, 11	Status of internal calibration is unknown
14	---	Spare bit
15	0	At least one scanner radiometric value PAT(559-1302) has both a good radiometric flag PAT(2139-2192) and a good FOV flag PAT(2201-2218)
	1	The above situation does not exist
Word 2 (PAT(2136))		
0-2	The scanner is in the following mode:	
	000	Normal Earth scan
	001	Nadir Earth scan
	010	Short Earth scan

	011	MAM scan
	100	Stowed position
	100,101,110,111	The mode of the scanner is undefined
3-5	The last azimuth command is given below. If the azimuth motor power is OFF (see Word 1, bit 6-7), then the azimuth position is given below. If the power is ON, the scanner is in transit to that azimuth position. A and B are stored azimuth values.	
	000	Go to azimuth position A
	001	Go to azimuth position B
	010	Go to azimuth = 0 degrees
	011	Go to azimuth = 90 degrees
	100	Go to azimuth = 180 degrees
	101	Azimuth is continuously changing between 0 deg. and A, or go from 0 deg. to A, then A to 0 deg., then 0 deg. to A, etc.
	110,111	The last azimuth command is undefined
6-8	The last SWICS (shortwave internal calibration source) command is given below:	
	000	Turn power OFF
	001	Go to power level 3
	010	Go to power level 3 and modulate (turn power ON and OFF)
	011	Go to power level 2
	100	Go to power level 2 and modulate
	101	Go to power level 1
	110	Go to power level 1 and modulate
	111	The last SWICS command is undefined
9-11	The azimuth position during solar calibration (see Word 1, bits 10-11) is given below. A and B are stored azimuth values.	
	000	Azimuth at B
	001	Azimuth at A prior to sun encounter
	010	Azimuth at neither A nor B
	011	Azimuth at A after sun encounter
	100,101,110,111	Azimuth position undefined
12	0	No new housekeeping data is available for this record, or the new data is questionable
	1	New housekeeping data is available for this record
13-15	---	Spare bits

NOTE: If PAT(2135) is positive (see bit position 15), at least one of the 248 scanner measurements on this record has a good radiometric flag and a good field-of-view flag. If PAT(2135) is negative, no scanner measurement has both flags set to good.

PAT(2137-2138) - Flag word, nonscanner operations. This is a record level flag and defines the nonscanner condition during the 16-second record. Each bit of this 2-word flag is defined in Table 5.

Table 5. PAT Flag Words, Noncanner Operations

Bit Position (Right to Left)	Bit Value	Meaning
Word 1 (PAT(2137)):		
0	0	Instrument power in ON
	1	Instrument power in OFF
1-2	00	Calculating solar monitor and Earth-viewing vectors
	01	Calculating solar monitor-viewing vectors only
	10, 11	Not calculating viewing vectors
3	0	No telemetry data drop out
	1	Telemetry data drop out due to:

		a) Previous record missing;
		b) Nonscanner instrument disabled on previous record; or
		c) Nonscanner command echo bad on previous record
4-5	00	No new command
	01	New command
	10, 11	Not defined, or a new command not understandable
6	0	New mode command
	1	No new mode command
7-8	00	First record after the end of a solar calibration sequence
	01	First record after the end of an internal calibration sequence
	10, 11	None of the above
9	0	In solar calibration sequence
	1	Not in solar calibration sequence or status unknown
10	0	In internal calibration sequence
	1	Not in internal calibration sequence or status unknown
11-12	The last instrument elevation command is given below:	
	00	Go to nadir (Earth view)
	01	Go to solar ports (non-Earth view)
	10	Go to internal sources (non-Earth view)
	11	The last elevation command is undefined
13-14	---	Spare bits
15	0	At least one nonscanner radiometric value PAT(1303-1382) has both a good radiometric flag PAT(2193-2200) and a good FOV flag PAT(2219-2220)
	1	The above situation does not exist
Word 2 (PAT(2138))		
0-2	The last SWICS (shortwave internal calibration source) command is given below:	
	000	Turn power OFF
	001	Go to power level 1
	010	Go to power level 2
	011	Go to power level 3
	100,101,110,111	The last SWICS command is undefined
3-4	The last solar monitor shutter command is given below:	
	00	Open shutter
	01	Close shutter
	10, 11	The last shutter command is undefined
5-6	The last WFOV blackbody heater command is given below. Positions 1 and 2 are stored temperatures	
	00	Turn heater OFF
	01	Go to temperature 1
	10	Go to temperature 2
	11	The last heater command is undefined
7-8	The last MFOV blackbody heater command is given below. Positions 1 and 2 are stored temperatures.	
	00	Turn heater power OFF

	01	Go to temperature 1
	10	Go to temperature 2
	11	The last heater command is undefined
9-10	The azimuth position during solar calibration is given below. A is a stored azimuth value.	
	00	Azimuth at position A
	01	Azimuth not at position A
	10,11	Position of azimuth undefined
11-15	---	Spare bits

NOTE: If PAT(2137) is positive (see bit position 15), at least one of the 20 nonscanner measurements on this record has a good radiometric flag and a good field-of-view flag. If PAT(2137) is negative, no scanner measurement has both flags set to good.

PAT(2139-2156) - Flag words, scanner, radiometric, total. These eighteen 16-bit values contain a single bit of information for each of the 248 measurements on the scanner total channel PAT(559-806). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2201).

NOTE: The 248 scanner flags are stored in eighteen 16-bit values where each flag is one bit. There are actually 270 information bits available and 18 high order sign bits. Only the first 14 information bits in each 16-bit value are used and only the first 10 bits are used in the last 16-bit value for a total of (14) (17) + 10 = 248 bits. The unused information bits and sign bits are set to zero. For example, if the first 25 total channel measurements were bad (1) and the remainder were good (0), we would have the following bit values:

PAT(2139) = 0011 1111 1111 1111
PAT(2140) = 0000 0111 1111 1111
PAT(2141) = 0000 0000 0000 0000
....
....
....
PAT(2156) = 0000 0000 0000 0000

PAT(2157-2174) - Flag words, scanner, radiometric, shortwave. These eighteen 16-bit values contain a single bit of information for each of the 248 measurements on the scanner shortwave channel PAT(807-1054). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2201). See PAT(2139) NOTE.

PAT(2175-2192) - Flag words, scanner, radiometric, longwave. These eighteen 16-bit values contain a single bit of information for each of the 248 measurements on the scanner longwave channel PAT(1055-1302). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2201). See PAT(2139) NOTE.

PAT(2193-2194) - Flag words, WFOV, radiometric, total. These two 16-bit values contain a single bit of information for each of the 20 measurements on the WFOV total channel PAT(1303-1322). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2219).

NOTE: The 20 scanner flags are stored in two 16-bit values where each flag is one bit. There are actually 30 information bits available and 2 high order sign bits. Only the first 10 information bits in each 16-bit value are used. The unused information bits and sign bits are set to zero. For example, if the second radiometric value was good (0) and the other 19 values were bad (1), we would have the following bit values:

PAT(2193) = 0000 0011 1111 1101
PAT(2194) = 0000 0011 1111 1111

PAT(2195-2196) - Flag words, WFOV, radiometric, shortwave. These two 16-bit values contain a single bit of information for each of the 20 measurements on the WFOV shortwave channel PAT(1323-1342). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2219). See PAT(2193) NOTE.

PAT(2197-2198) - Flag words, MFOV, radiometric, total. These two 16-bit values contain a single bit of information for each of the 20 measurements on the MFOV total channel PAT(1343-1362). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2219). See PAT(2193) NOTE.

PAT(2199-2200) - Flag words, MFOV, radiometric, shortwave. These two 16-bit values contain a single bit of information for each of the 20 measurements on the MFOV shortwave channel PAT(1363-1382). If the bit value is zero, the corresponding radiometric value is good data. If the bit value is one, the data is bad. These radiometric flags are independent of the FOV flags PAT(2219). See PAT(2193) NOTE.

PAT(2201-2218) - Flag words, scanner, FOV. These eighteen 16-bit values contain a single bit of information for each of the 248 scanner FOV's, PAT(23-518). A bit value of zero denotes a good FOV and a value of one denotes a bad FOV. See PAT(2139) NOTE.

NOTE: A good FOV corresponds to a value of 000, 001, or 010 from the following table. Otherwise, the FOV is bad. An Earth scan mode can be either a normal Earth scan, a nadir Earth scan, or a short scan (see PAT(2136) bits 0-2). If the scanner mode is MAM scan, stowed position, or undefined, then the FOV is set to bad.

Bit Value of Full Scanner FOV Flag(not given on PAT)	Meaning of Earth Scans
000	All the scan FOV is sunlit
001	None of the scan FOV is sunlit
010	Scan FOV is partially sunlit
011, 100	Scan FOV is off horizon and only partially viewing Earth
101	Scanner is viewing space
110	Scanner is viewing an internal source (stowed)
111	Scan FOV condition is undefined

PAT(2219-2220) - Flag words, nonscanner, FOV. These two 16-bit values contain a single bit of information for each of the 10 nonscanner FOV's, PAT(519-558). A bit value of zero denotes a good FOV, and a value of one denotes a bad FOV. If the elevation command of the nonscanner (PAT(2137)), bit (11-12) is non-Earth view or undefined, all 20 FOV's are considered bad. Otherwise, these bits are a condensation of the information in PAT(3511-3550).

The wide FOV is considered good if PAT(3511), etc. contains a value of 0000, 0001, 0010, 0011, or 0100. Otherwise, the FOV is bad. The medium FOV is considered good if PAT(3531), etc. contains a value of 0000, 0001, or 0010 and is bad for any other value. For the nonscanner FOV to be good as denoted by PAT(2219-2220), both the wide and medium FOV's must be good. Otherwise, the nonscanner FOV is bad.

PAT(2221-2468) - Scanner, unfiltered, shortwave. This is the unfiltered scanner shortwave measurement at satellite altitude and is set equal to zero at night ($Wm^{-2}\ sr^{-1}$).

NOTE: An unfiltered scanner measurement is the integral over wavelength λ of the product of the true spectral radiance L_λ incident on the instrument and a "perfectly flat" instrument spectral response C_λ , or

$$m^i = \int_0^\infty C_\lambda L_\lambda \, d\lambda \qquad i = \text{shortwave, longwave}$$

where

$$C_\lambda^{SW} = \begin{cases} 1 & 0 \le \lambda \le 5 \quad \mu m \\ 0 & \text{elsewhere} \end{cases}$$

$$C_\lambda^{LW} = \begin{cases} 0 & 0 \le \lambda \le 5 \quad \mu m \\ 1 & \text{elsewhere} \end{cases}$$

The unfiltered measurements are estimated from the filtered measurements m^i_F (see PAT(559)) by

$$m^{SW} = B_1 m_F^{TOT} + B_2 (m_F^{SW} - 0^{SW}) + B_3 m_F^{LW}$$

$$m^{LW} = B_4 m_F^{TOT} + B_5 (m_F^{SW} - 0^{SW}) + B_6 m_F^{LW}$$

where the B's are regression coefficients and a function of scene type, directional angles, colatitude of the target point, and which filtered measurements are "good". 0^{SW} is a shortwave offset that is either zero or the average nighttime shortwave measurement for the previous nighttime passage. 0^{SW} is updated each satellite revolution or as often as 15 times for a 24-hour period. See PAT(3241), PAT(1383), PAT(1631), PAT(1879), PAT(23), PAT(2139), PAT(2157), and PAT(2175).

PAT(2469-2716) - Scanner, unfiltered, longwave. This is the unfiltered scanner longwave measurement at satellite altitude ($Wm^{-2}sr^{-1}$). See PAT(2221) NOTE.

PAT(2717-2964) - Scanner, TOA estimate, shortwave. This is an estimate of the shortwave radiance exitance at the scanner target point. It is set equal to zero at night (Wm^{-2}).

NOTE: The shortwave scanner measurement at satellite altitude is inverted to the TOA as follows:

θ_s' = PAT(1383) = viewing zenith
θ_o' = PAT(1631) = solar zenith
ϕ' = PAT(1879) = relative azimuth
i = PAT(3241) = scene type
m^{SW} = PAT(2221) = shortwave measurement

and

$$\hat{M}^{SW} = \frac{\pi m^{SW}}{R^i(\theta_s', \theta_0', \phi')}$$

where $\hat{M}^{SW}$ is an estimate of the shortwave radiant exitance at the scanner target point and R is the shortwave bidirectional function for the given scene type and directional angles. The shortwave scanner measurement is not inverted to the OA if $\theta_s' \geq 70°$, $\theta_o' \geq 86.5°$, R^i >= 2, or m^{SW} is default.

PAT(2965-3212) - Scanner, TOA estimate, longwave. This is an estimate of the longwave radiant exitance at the scanner target point (Wm^{-2}).

NOTE: The longwave scanner measurement at satellite altitude is inverted to the TOA as follows:

θ_s' = PAT(1383) = viewing zenith
θ_t = PAT(23) = target point colatitude
i = PAT(3241) = scene type
m^{LW} = PAT(2469) = longwave measurement

and

$$\hat{M}^{LW} = \frac{\pi m^{LW}}{R^i(\theta_s', \theta_t)}$$

where $\hat{M}^{LW}$ is an estimate of the longwave radiant exitance at the scanner target point and R is the longwave anisotropic function for the given scene type and directional angles. The longwave scanner measurement is not inverted to the TOA if $\theta_s' \geq 70°$ or m^{LW} is default.

PAT(3213-3216) - WFOV, unfiltered, shortwave. This is the unfiltered WFOV shortwave measurement at satellite altitude and is set equal to zero when the entire FOV is at night (Wm^{-2}).

NOTE: An unfiltered nonscanner measurement is modeled as a triple integral over wavelength and solid angle. The first integral is over wavelength λ of the product of the true spectral radiance, L_λ , incident on the instrument and a "perfectly flat" instrument spectral response, C_λ. This spectral radiance is then weighted by a flat plate cosine response cos ζ and integrated over FOV, or

$$m^i = \int_{\xi=0}^{2\pi} \int_{\zeta=0}^{\zeta_b} \int_{\lambda=0}^{\infty} C_\lambda^i L_\lambda(\zeta,\xi) \cos\zeta \sin\zeta \, (d\lambda)\,(d\zeta)\, d\xi$$

i = shortwave, longwave

where

$$C_\lambda^{SW} = \begin{cases} 1 & 0 \leq \lambda \leq 5 \quad \mu m \\ 0 & \text{elsewhere} \end{cases}$$

$$C_\lambda^{LW} = \begin{cases} 0 & 0 \leq \lambda \leq 5 \quad \mu m \\ 1 & \text{elsewhere} \end{cases}$$

and where ζ is the nadir or cone angle and ξ is the clock angle. The integration over the nadir angle is from 0 (straight down) to ζ_b which is the angle to the boundary of the FOV.

The unfiltered measurements are estimated from the filtered measurement m_F^i (see PAT(1303)) by

$$m^{SW} = m_F^{SW} - 0^{SW}$$

$$m^{LW} = m_F^{TOT} - m^{SW}$$

where 0^{SW} is a shortwave offset that is either zero or the average nighttime shortwave measurement for the previous nighttime passage. 0^{SW} is updated each satellite revolution or as often as 15 times for a 24-hour period.

The unfiltered nonscanner measurements are recorded on the PAT every 4 seconds so that there are 4 measurements per 16-second PAT record.

PAT(3217-3220) - WFOV, unfiltered, longwave. This is the unfiltered WFOV longwave measurement at satellite altitude (Wm^{-2}). See PAT(3213) NOTE.

PAT(3221-3224) - MFOV, unfiltered, shortwave. This is the unfiltered MFOV shortwave measurement at satellite altitude and is set equal to zero when the entire FOV is at night (Wm^{-2}). See PAT(3213) NOTE.

PAT(3225-3228) - MFOV, unfiltered, longwave. This is the unfiltered MFOV longwave measurement at satellite altitude (Wm^{-2}). See PAT(3213) NOTE.

PAT(3229) - WFOV, TOA estimate, NF, shortwave. This is an estimate of the shortwave radiant exitance at the TOA as derived from WFOV measurements and the numerical filter inversion technique. The location of the estimate is taken as the spacecraft nadir point (PAT(16) and PAT(18)) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}).

NOTE: The numerical filter uses a sequence of 13 average nonscanner measurements $\bar{m}_j$ to derive an estimate of radiant exitance $\hat{M}$ at the TOA. Each average measurement combines 32 seconds of nonscanner unfiltered measurements. Thus, a single estimate is affected by measurements over a 416 second time interval or 26 PAT records. The numerical filter estimate is given by

$$\hat{M}^i = \sum_{j=-6}^{6} w_j^i \, \bar{m}_j^i$$

i = shortwave, longwave

For shortwave the inversion weights w_j are a function of the orbital geometry and the scene information (PAT(3241)) as derived from the scanner measurements. For longwave the inversion weights are constants.

PAT(3230) - WFOV, TOA estimate, NF, longwave. This is an estimate of the longwave radiant exitance at the TOA as derived from WFOV measurements and the numerical filter inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3229) NOTE.

PAT(3231) - MFOV, TOA estimate, NF, shortwave. This is an estimate of the shortwave radiant exitance at the TOA as derived from MFOV measurements and the numerical filter inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3229) NOTE.

PAT(3232) - MFOV, TOA estimate, NF, longwave. This is an estimate of the longwave radiant exitance at the TOA as derived from MFOV measurements and the numerical filter inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3229) NOTE.

PAT(3233) - WFOV, TOA estimate, SF, shortwave. This is an estimate of the shortwave radiant exitance at the TOA as derived from WFOV measurements and the shape factor inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}).

NOTE: The shape factor technique inverts a single average measurement $\bar{m}$ to derive the estimate of radiant exitance $\hat{M}$ at the TOA. The average measurement combines 32 seconds of nonscanner unfiltered measurements. The shape factor estimate is given by

$$\hat{M}^i = \frac{\bar{m}^i}{SF^i} + B^i$$

i = shortwave, longwave

where the parameters SF and B are obtained in one of three ways which is recorded in PAT(3489).

The first way of obtaining the inversion parameters is to set B = 0 and derive SF by assuming albedo and longwave radiant exitance are constant over the FOV. For shortwave the scene information PAT(3241) is derived from the scanner measurements so that SF varies with spacecraft position. For longwave the F is constant.

The second way of obtaining the inversion parameters is to set B = 0 and derive SF by assuming albedo and longwave radiant exitance are constant over the FOV. This approach differs from the first approach in that the shortwave scene is assumed overcast and does not require scanner scene information. The longwave SF is constant.

The third way of obtaining the inversion parameters is to define B and SF as regression coefficients based on a simulation study. These parameters will be independent of scene information and are given by

SF^{SW} = function of solar zenith at nadir (PAT(2129))
B^{SW} = function of solar zenith at nadir (PAT(2129))
SF^{LW} = constant
B^{LW} = 0

PAT(3234) - WFOV, TOA estimate, SF, longwave. This is an estimate of the longwave radiant exitance at the TOA as derived from WFOV measurements and the shape factor inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3233) NOTE.

PAT(3235) - MFOV, TOA estimate, SF, shortwave. This is an estimate of the shortwave radiant exitance at the TOA as derived from MFOV measurements and the shape factor inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3233) NOTE.

PAT(3236) - MFOV, TOA estimate, SF, longwave. This is an estimate of the longwave radiant exitance at the TOA as derived from MFOV measurements and the shape factor inversion technique. The location of the estimate is taken as the spacecraft nadir point PAT(16) at either the beginning or end of the 16-second PAT record (see PAT(3489)) (Wm^{-2}). See PAT(3233) NOTE.

PAT(3237-3240) - Spares. These are spares and not used.

PAT(3241-3488) - Scanner, FOV, scene ID. This is the ERBE scene classification of the scanner FOV. The 13 possible scene types are:

PAT Value	Description of Scene
0.X	unknown scene
1.X	clear ocean
2.X	clear land
3.X	clear snow
4.X	clear desert
5.X	clear land-ocean mix
6.X	partly cloudy over ocean
7.X	partly cloudy over land or desert
8.X	partly cloudy over land-ocean mix
9.X	mostly cloudy over ocean
10.X	mostly cloudy over land or desert
11.X	mostly cloudy over land-ocean mix
12.X	overcast

where X equals 0, 1, 2, 3, 4 for ocean, land, snow, desert, land-ocean mix, respectively. The decimal defines the geographic scene so that 12.1 would indicate overcast over land. Care should be taken in determining the geographic scene because of computer characteristics. A useful Fortran code is

```
ISCENE = NINT(XPAT(3241))
IX = NINT((XPAT(3241) - REAL(ISCENE)) * 10.0)
```
where NINT is the nearest integer operator.

A land-ocean mix scene denotes 50 percent land and 50 percent ocean and is used for coastal areas. Clear scenes have zero percent to five percent cloud cover. Partly cloudy scenes have five to 50 percent cloud cover and mostly cloudy scenes have 50 to 95 percent cloud cover. An overcast scene denotes 95 to 100 percent cloud cover.

NOTE: Base on the unfiltered scanner measurements,

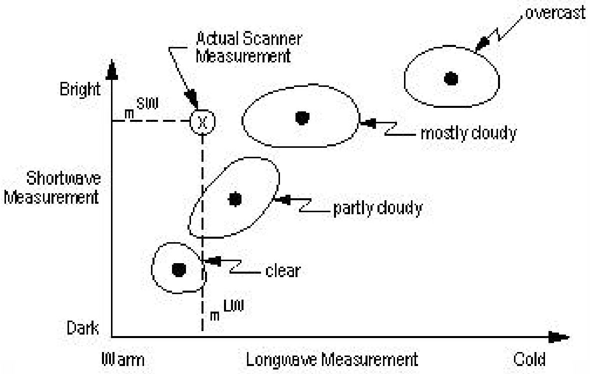
m^{SW} = PAT(2221)

and

m^{LW} = PAT(2469),

the scene corresponding to each scanner measurement is identified as one of four cloud conditions over a predetermined geographic or surface type. The first step is to determine the 2.5 degree region that contains the scanner target point given by PAT(23) and PAT(271). From physical data, we then determine the geographic scene as either ocean, land, snow, desert, or land-ocean mix. Next we determine the cloud condition.

An example of a typical scene identification is shown in the following figure. Knowing the geographic scene and the directional angles PAT(1383), PAT(1631), and PAT(1879), we can evaluate from apriori data measurements we would expect from a clear sky, partly cloudy, mostly cloudy, and overcast conditions. The ellipse about each point represents the variance we would expect. The identification consists of determining which one of the four cloud conditions produced the actual measurement or which is the closest point in a probabilistic sense.



PAT(3489) - Flag, nonscanner, TOA estimate. The nonscanner TOA estimates occur every 32 seconds and are recorded every 16 seconds on the PAT tape. Thus, the same estimate will appear on two consecutive PAT records where the location of the estimate is the end of the first record and the beginning of the second record. This information, along with the specific shape factor technique, is recorded in this flag as defined below (X denotes any value).

Bit Value	Description
XXXXXXX0	All nonscanner estimates PAT(3229-3236) are located at the beginning of the record at PAT(16) and PAT(18)
XXXXXXX1	All nonscanner estimates PAT(3229-3236) are located at the end of the record at PAT(17) and PAT(19)
XXXXX00X	The nonscanner shape factor estimates PAT(3233-3236) were derived using the first approach. (See PAT(3233) NOTE)
XXXXX01X	The nonscanner shape factor estimates PAT(3233-3236) were derived using the second approach. (See PAT(3233) NOTE)
XXXXX10X	The nonscanner shape factor estimates PAT(3233-3236) were derived using the third approach. (See PAT(3233) NOTE)

PAT(3490-3510 - Spares. These are spares and not used.

PAT(3511-3530) - Flag, nonscanner, WFOV. This flag corresponds to the WFOV measurements PAT(1303-1342). Each value is 4 bits and has a different meaning depending on whether the instrument is in the Earth view or non-Earth view mode (see PAT(2137), bit 11-12). If the operations mode is undefined, then PAT(3511-3530) is set equal to 0111. Each value of this flag is defined below.

Bit Value (PAT Value)	Earth View Mode	Non-Earth View Mode
0000 (0)	All of the wide FOV is sunlit	The WFOV instrument is viewing the full sun disc
0001 (1)	None of the wide FOV is sunlit	The WFOV instrument is viewing only part of the sun disc
0010 (2)	Wide FOV is partially sunlit and medium FOV is full sunlit	The WFOV instrument is viewing none of the sun disc after viewing the sun
0011 (3)	Wide FOV is partially sunlit and none of medium FOV is sunlit	The WFOV instrument is viewing none of the sun disc after viewing the sun
0100 (4)	Wide FOV is partially sunlit and medium FOV is partially sunlit	The WFOV instrument is viewing an internal source
0101 (5)	There is space ring loss. The WFOV instrument is pointing off nadir and does not view the entire Earth disc. Also, 0110 and 0111 have not occurred	Spare
0110 (6)	There is solar impingement. Part of the wide FOV boundary is near the solar terminator so that direct sunlight is striking the WFOV instrument. Also, 0111 has not occurred.	Spare
0111 (7)	Not enough information to determine the wide FOV condition; or the WFOV optical axis does	Not enough information to determine the wide FOV condition; or the WFOV instrument is in

	not intersect the Earth TOA.	the slew mode.

NOTE: The FOV as used in the definitions of PAT(3511-3550) is defined as the area at the top of a spherical TOA viewed by the nonscanner. The boundary of this area is the intersection of the viewing cone from the spacecraft and the spherical TOA. If the sun terminator (great circle) intersects this boundary, the FOV is partially sunlit (0010). Otherwise, it is full sunlit (0000) or totally dark (0001).

PAT(3531-3550) - Flag, nonscanner, MFOV. This flag corresponds to the MFOV measurements PAT(1343-1382). Each value is 4 bits and has a different meaning depending on whether the instrument is in the Earth view or non-Earth view mode (see PAT(2137)). Each value of this flag is defined below. See PAT(3511) NOTE.

Bit Value (PAT Value)	Earth View Mode	Non-Earth View Mode
0000 (0)	All of the medium FOV is sunlit	The MFOV instrument is view the full sun disc
0001 (1)	None of the medium FOV is sunlit	The MFOV instrument is viewing only part of the sun disc
0010 (2)	The medium FOV is partially sunlit	The MFOV instrument is viewing none of the sun disc prior to viewing the sun
0011 (3)	All of the medium FOV is sunlit and there is a target point error	The MFOV instrument is viewing none of the sun disc after viewing the sun
0100 (4)	None of the medium FOV is sunlit and there is a target point error	The MFOV instrument is viewing an internal source
0101 (5)	The medium FOV is partially sunlit and there is a target point error	Spare
0110 (6)	Spare	Spare
0111 (7)	Not enough information to determine the medium FOV condition; or the MFOV optical axis does not intersect the Earth TOA.	Not enough information to determine the medium FOV condition; or the MFOV instrument is in the slew mode.

NOTE: A target point error implies that the nadir angle of the medium FOV optical axis (normally zero) is greater than δ_b. The nadir angle is the angle at the spacecraft between a vector from the spacecraft to the center of the Earth and a vector from the spacecraft to the MFOV target point (see PAT(1383) NOTE). The value of δ_b is a suitably chosen system constant.

PAT(3551-3630) - Spares. These are spares and not used.

Unit of Measurement:

Units of measurement for the calculated and measured science variables for the S-8 data product can be found in the Variable Description/Definition Section of this document.

Data Source:

Please refer to the Summary of Parameters Section of this document.

Data Range:

...

Sample Data Record:

ERBE data records are quite large (on the order of 104 or 105 binary bytes per record). Reproducing sample records of this size in a document of this sort is impractical.

8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

All data granules consist of one day of data.

Data Format:

The first file on the PAT is generated by a CDC computer program on a 9-track, 1600 bpi, unlabeled tape. Each tape contains four files. The first file contains the standard ERBE header record. The second file contains a test PAT record which is used to validate the unpacking process. The third file contains two records. The first record contains 3630 scale factors and the second record contains 3630 offsets. The fourth file contains the 16-second ERBE data records.

Standard ERBE Header Record. The first file on the PAT contains one header record which identifies the data on the tape and serves as an identifying number for any correspondence between a user and the ERBE Data Management Team. It is a 30-byte record formatted as 8-bit bytes and defined by Table 6. An example of the information in this header for the PAT is given in Table 7.

Table 6. Standard ERBE Header Record

Bytes	Position	Value	Interpretation
1-2	Subsystem Indicator	1-7	The subsystem outputting the data product is: 1 - Telemetry 2 - Ephemeris 3 - Attitude 4 - Merge/FOV/Count Conversion 5 - Inversion 6 - Daily Data Base & Monthly Time/Space Averaging 7 - Output Products
3-4	Product Code	1-99	Each subsystem assigns its output (tape, disc, paper, plot, etc.) a unique number for identification. (Reference 3)
5-6	Spacecraft Indicator	1-7	The data is from the following combination of spacecrafts: 1 - NOAA-9 only 2 - ERBS only 3 - NOAA-10 only 4 - NOAA-9 and NOAA-10 5 - NOAA-9 and ERBS 6 - NOAA-10 and ERBS 7 - NOAA-9 and NOAA-10 and ERBS
7-8	Whole Julian date (high-order part)	e.g.,244	Leftmost 3 digits of the 7-digit whole part of the initial Julian date
9-10	Whole Julian date (low-order part)	e.g.,5700	Rightmost 4 digits of the 7-digit whole part of the initial Julian date
11-12	Fractional Julian date	e.g.,5000	First 4 digits of the fractional part of the initial Julian date times 10000
13-14	Processed Version Counter	1-99	A counter initially set to 1 and incremented by one each time the product is reprocessed
15-16	Year Processed	e.g.,84	The last two digits of the year of process date. The process date is the date (local time) when the data product was processed (or reprocessed) at Langley Research Center, Hampton, VA
17-18	Month Processed	12	Month of the process date. January is 1 and December is 12
19-20	Day Processed	1-31	Day of the process date
21-22	Hour Processed	0-23	Hour of the process date
23-24	Minute Processed	0-59	Minute of the process date
25-26	Second Processed	0-59	Second of the process date
27-30	Spares	0	Zero-filled spares to product a record which is a multiple of 8-, 16-, and 60-bits

Table 7. Example of PAT's ERBE Header Record

Bytes	Description	Example	Note
1-2	Subsystem Indicator	5	The PAT is output from the Inversion Subsystem and will always have a 5 as the subsystem indicator.
3-4	Product Code	9	The Inversion Subsystem has arbitrarily defined the product code for the monthly PAT as 9.
5-6	Spacecraft Indicator	2	Since the PAT is for a single spacecraft, only a 1, 2, or 3 is appropriate here.
7-8	Whole Julian date (high-order part)	244	The initial Julian date, for example, is 2445700.5000 which corresponds to Greenwich midnight beginning January 1, 1984.
9-10	Whole Julian date (low-order part)	5700	The whole Julian date changes at Greenwich noon.
11-12	Fractional Julian date	5000	Since the first 24-hour period of a PAT file starts at Greenwich midnight, the fractional initial Julian date will be 0.5.
13-14	Processed Version Counter	1	A value of 1 means that the PAT has been processed one time and not reprocessed.
15-16	Year Processed	84	For this example, the PAT was processed on February 3, 1984 at 9 P.M. 48^M54^S.
17-18	Month Processed	2	
19-20	Day Processed	3	
21-22	Hour Processed	21	
23-24	Minute Processed	48	
25-26	Second Processed	54	
27-30	Spares	0	

Test PAT Record. The second file on the PAT contains a test PAT record. This record is a typical 16-second ERBE data record of 3630 quantities and is used to validate the unpacking process. It is read and unpacked in the same way as the ERBE data records. An unpacked version of this test record is given in Appendix A of the ERBE S-8 User's Guide. The same test record will be put on every PAT so that a user can validate the unpacking process. If the packed data is unpacked correctly, the test record should be identical to that given in Appendix A of the ERBE S-8 User's Guide.

Scale Factors and Offset Records. The first and second records of the third PAT file contain the 3630 scale factors and offsets, respectively. They have the same order and correspond one-to-one with the PAT data quantities as shown in Table 3. Each record contains 54720 bits which is divided into 32-, 16-, 8-, and 4-bit words to give the 3630 scale factors and offsets. Since these quantities are integers, they require no scaling themselves.They are used to unscale the integer data quantities as follows:

ith Real Quantity = (ith Integer Scaled Quantity from Tape) / (ith Scale Factor) - ith Offset
i = 1, 2, ... , 3630

The scale factors and offsets given in Table 3 re nominal values. The actual values used to scale the data are recorded on the PAT in the first and second records as discussed above. These are the values that should be used to scale the integer data on the tape and not the values in Table 3. However, the values on the PAT will probably be the same as those in Table 3.

Data Records. There are nominally 5400 16-second records (24 hours) on a PAT. Data dropout may reduce the number of records. The cumulative total bits for a single data record is 54720 bits. The data records are arranged in groups as shown:

No. of Bits per Word	No. of Words	Bits	Cumulative Total Bits	Default Value (No Data)
32	15	480	480	2^{32}-1
16	3225	51600	52080	2^{15}-1
8	270	2160	54240	2^{7}-1
4	120	480	54720	2^{4}-1

If no data exists for a PAT quantity, all bits are set as the default value. The scale factors and offsets should not be applied to the default values.

9.Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

...

Data Processing Sequence:

Processing Steps:

The Langley Research Center (LaRC) has the responsibility of processing and validating all science data from the ERBE mission and of distributing the resulting data products to the science community. The ERBE data processing system at LaRC uses a modular software subsystems approach to process the ERBE data, starting with the input telemetry and ephemeris data from Goddard Space Flight Center (GSFC) and NOAA and ending with the production of the required science data products.

The diagram in the Flowchart Figure shows the major steps in the science data processing, together with the primary input and output data products. The first step in this processing procedure is to ingest 24 hours of telemetry data from the ERBS, NOAA-9, or NOAA-10 spacecraft into the front-end processing subsystem of the Data Processing System. The processing at this step accounts for spacecraft differences and for differences in the data acquisition and handling systems of the ERBS and TIROS N satellites. The data are organized into a format that is common to data from GSFC and NOAA. Extensive data quality editing and evaluation are performed, including the checking of quality flags appended by the tracking networks and processing systems at GSFC and NOAA. The operational status of the instruments is determined, and all instrument housekeeping data and selected spacecraft housekeeping measurements are converted to engineering units and edited. Pointing vectors for the optical axes of the detectors are calculated in a local horizon coordinate system at the spacecraft.

The 8-day ephemeris data sets are processed and validated separately before combining them with the corresponding telemetry data. Orbital data are tested for consistency with data from the previous week, and tests are performed to verify the consistency of the orbit calculations between 1-minute data points. The tests include checks for in-plane and out-of-plane consistency and precision. The routine verification processing and other analyses performed to verify the accuracy of the ephemeris data have generally demonstrated accurate orbit determination for both the ERBS and NOAA spacecraft.

The next major processing stage begins with the merging of the output data from telemetry processing with data output from the ephemeris processing. The FOV locations on a surface at the TOA are determined for every radiometric measurement. The FOV locations are more critical for the scanner measurements than those of the nonscanner because of the small FOV of the scanner instrument. A FOV accuracy analysis has shown that the calculated locations of the scanner measurements are well within the FOV footprint of the instrument on the Earth.

At this processing stage, the raw measurements for each radiometric detector are also converted to incident radiances at the spacecraft. The conversion algorithms employ calibration coefficients that are based primarily on ground-based calibration data, but which are updated with results from in-flight calibrations.

In the inversion processing stage, data from the scanner detectors are used to identify the type of scene or source at the TOA that produced the raw radiometric measurements. Based on the scene type and geographical location, the scanner measurements are adjusted to account for changes in the spectral response in each detector. Using the selected scene-type, one of several angular directional models is selected for inverting or reducing the measurements from satellite altitude to radiant fluxes at the TOA. The nonscanner measurements are inverted using scene information determined during scanner data processing and two different inversion algorithms. One algorithm employs geometric shape factors and the other employs numerical filtering. An archival product, called the Processed Archival Tape (PAT), is produced at this point to retain detailed time histories of estimates of the radiant fluxes at the TOA.

The time-ordered estimates of TOA fluxes are sorted into spatial sequences for both the scanner and nonscanner measurements, grouping all estimates for a month together on a regional basis. A full calendar month of estimates is then retrieved for each region of the Earth. Hourly, daily, and monthly estimates of several different parameters are derived by interpolation using directional models that describe the temporal variation of the radiation budget components. Archival products of monthly averages of radiation components for both the scanner and nonscanner are produced at this point.

Several archival products are produced at the final stage of data processing. The nested averages product gives values of the scanner and nonscanner fluxes from each instrument averaged over various spatial scales. The processing at this stage also combines data from all available spacecraft to produce a combined- satellite product of TOA fluxes averaged over the same spatial scales. An archival product for solar monitor measurements is also produced to provide time histories of solar calibration data. Finally, a scene validation product is produced that combines ERBE data with measurements from the AVHRR and the HIRS instruments. Data from these two NOAA instruments are used to validate the scene identification algorithm. Currently all archival data products are distributed first to the ERBE Science Team for review and validation and then to LaRC ASDC for archival.

Processing Changes:

There are no plans for reprocessing.

Calculations:

Special Corrections/Adjustments:

...

Calculated Variables:

Please refer to the Variable Description/Definition Section of this document.

Graphs and Plots:

There are no graphs/plots available.

10. Errors:

Sources of Error:

A discussion of various factors that may lead to errors are discussed in the Confidence Level/Accuracy Judgement Section of this document.

Quality Assessment:

Data Validation by Source:

The measurement of radiation budget requires a massive data processing system. ERBE's system uses about 250,000 lines of FORTRAN code. This system also uses an additional 150,000 lines of off-line diagnostic work. The stringent requirements for accuracy in the budget dictate an acute attention to detail.

The ERBE data processing system uses about 25,000 coefficients. These coefficients are conveniently arranged in three groups. The first group is the set of "calibration coefficients" that appear in the algorithms converting telemetry counts to instrument irradiation. Ground- and in-flight-calibration sources provided these coefficients. The second group includes the angular distribution models (ADMs) and spectral unfiltering coefficients needed for inversion. A categorization of the Nimbus-7 ERB measurements forms the base for the ADM's. Missing bins were filled using the reciprocity principle. A combination of radiative transfer results and measurements of the instrument spectral responses provides the spectral correction coefficients. The third and final group of parameters consists of the coefficients needed for time averaging, mainly the directional models. These models describe the dependence of each scene type's albedo upon solar zenith angle. These directional models also came from the Nimbus-7 ERB, but have been suitably supplemented by Geostationary Operational Environmental Satellite (GOES) observations where needed. The majority of the coefficients come from the inversion process.

The earth's radiation budget is not easy to measure, even indirectly. The ERBE Science Team has relied on consistency and measurement intercomparisons for validation. Fortunately, ERBE data provides a number of these checks. The Science Team chose ten of these as validation criteria. These criteria provide a way of judging the consistency of the various parameters in the data processing system.

Confidence Level/Accuracy Judgement:

The ERBE data products are complex assemblages of data and models. Thus, their uncertainties are difficult to compute. The following numbers represent estimates of the standard deviations about a given data point within which the true measurement might lie. They are not definitive confidence intervals, but are intuitively based on the observed discrepancies in the intercomparisons. It is also important to remember that different measurements have different uncertainties. First, for instantaneous radiances, we expect uncertainties of about 10f longwave observations of filtered radiance and 2 0.000000or shortwave. Radiative transfer comparison and spectral consistency provide the basis for this uncertainty estimate. Second, on an instantaneous observation of flux from 2.5 x 2.5 degree geographic regions, the ERBS/NOAA-9 intercomparisons offer reasonable estimates of uncertainty. These are 5 Wm^{-2} in the longwave and 15 Wm^{-2} in the shortwave. Third, on a monthly average, regional basis, the uncertainties in the scanner data are about 5 Wm^{-2} for shortwave and 5 Wm^{-2} for longwave. These come from simulations with GOES data. This uncertainty represents no change from the preflight estimate. The nonscanner averages may be somewhat more uncertain because of sampling and diurnal averaging process. Fourth, the uncertainty in global, annual average net radiation is probably about 5 Wm^{-2}. This estimate is based on the imbalance obtained using scanner data from the four validation months (April, July, and October 1985; January 1986).

Measurement Error for Parameters:

A discussion of measurement error is found in the Confidence Level/Accuracy Judgement Section of this document.

Additional Quality Assessments:

None.

Data Verification by Data Center:

The data were received on 12 inch worm media. Before the data were archived, the ASDC checked all granules to ensure that the size of the granules matched that what was delivered on the media. The version number of the granules were also checked so that the most current version of the data are available to the user community. Granule level metadata were extracted from the granules such as the product ID, satellite(s) ID, and data date.

11. Notes:

Limitations of the Data:

There are no known limitations or unreliable aspects in the algorithms implemented to generate the ERBE science data.

Known Problems with the Data:

There are no known problems or inconsistencies in the ERBE data.

Usage Guidance:

A monthly product summary is currently produced for the PAT, and S-7 data, which includes an explanation of the data coverage for the month. In those rare instances when an archive tape is not produced, reasons and explanations for this are also included in the monthly summary report.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

Measurements of the radiation budget provide one of the important tools for the validation of numerical models of the atmosphere. They also provide possibilities for "climate experiments" by allowing the sensitivity of the radiation budget to various forcings to be studied empirically.

The use of cloud discrimination has provided a significant new source of information on the influence of clouds and the characteristics of clear-sky fluxes. This information is particularly important in understanding cloud forcing. It is also important in describing the response of clouds to climate change: the climate cloud sensitivity.

13. Future Modifications and Plans:

The ERBE project plans to complete the reprocessing, which is currently in progress, of the nonscanner data using inversion and time/space averaging processes which do not use scanner scene identification information.

Current plans are to reprocess the ERBE scanner data beginning in 1996 using the CERES algorithms.

To continue the measurements of the radiation budget, a second project, the Clouds and the Earth's Radiant Energy System (CERES), is currently being developed. CERES is a key component of the Earth Observing System (EOS). The CERES instruments are improved models of the Earth Radiation Budget Experiment (ERBE) scanner instruments. The strategy of flying instruments on Sun-synchronous, polar orbiting satellites, such as NOAA-9 and NOAA-10, simultaneously with instruments on satellites that have precessing orbits in lower inclinations, such as ERBS, was successfully developed in ERBE to reduce time sampling errors. CERES will continue that strategy by flying instruments on the polar orbiting EOS platforms simultaneously with an instrument on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, which has an orbital inclination of 35 degrees. In addition, to reduce the uncertainty in data interpretation and to improve the consistency between the cloud parameters and the radiation fields, CERES will include cloud imager data and other atmospheric parameters. The first CERES instrument is scheduled to be launched on the TRMM spacecraft in 1997. Additional CERES instruments will fly on the EOS-AM platforms, the first of which is scheduled for launch in 1998, and on the EOS-PM platforms, the first of which is scheduled for launch in 2000.

14. Software:

Software Description:

Read software is available for this data set.

Software Access:

The software can be obtained through the Langley ASDC. Please refer to the contact information below. The software can also be obtained at the same time the user is ordering this data set.

15. Data Access:

Contact Information:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Data Center Identification:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Procedures for Obtaining Data:

The Langley ASDC Information Management System (IMS) is an on-line system that features a graphical user interface (GUI) which allows the user to query the Langley ASDC data set holdings, to view pre-generated browse products, and to order specific data products.

The Langley ASDC User and Data Services (UDS) staff provides technical and operational support for users ordering data.

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov
URL: http://eosweb.larc.nasa.gov

Data Center Status/Plans:

On a regular basis, individual ERBE data granules are reviewed by local members of the ERBE Science Team. Upon Science Team approval, the ERBE Data Management Team releases the data granule to the LaRC ASDC for archive.

16. Output Products and Availability:

No additional output products are available for the ERBE S-8 data set.

17. References:

1. ERBE Data Management System, December, 1987. Processed Archival Tape S-8 PAT Users' Guide.

2. Kopia, L.P., 1986. "The Earth Radiation Budget Experiment Scanning Instrument," Reviews of Geophysics and Space Physics, 24, 400-406.

3. Luther, M.R., J.E. Cooper, and G.R. Taylor, 1986. "The Earth Radiation Budget Experiment Nonscanning Instrument," Reviews of

Geophysics and Space Physics, 24, 391-399.

4. Smith, G.L., R.N. Green, E. Raschke, L.M. Avis, B.A. Wielicki, and R. Davies, l986. "Inversion Methods for Satellite Studies of the Earth's Radiation Budget: Development of Algorithms for the ERBE Missions." Rev. of Geophys., 24:407-421.

5. Sorlie, S., February 1993. "Langley DAAC Handbook." NASA/Langley Research Center, Hampton, Virginia.

18. Glossary of Terms:

EOSDIS Glossary.

Albedo
The ratio of shortwave radiant flux to the integrated solar incidence, where zero (0.0) represents total absorption, and one (1.0) represents total reflectance.

Nadir
That point on the celestial sphere vertically below the observer, or 180 degree from the zenith.

Radiance
The radiant flux per unit solid angle per unit of projected area of the source; usual unit is the Watt per square meter per steradian. Also known as steradiancy.

Radiant Flux
The time rate of flow of radiant energy. Usual unit is the Watt per square meter.

S-8: Processed Archival Tape
The S-8 contains ERBE scanner and nonscanner radiometric measurements for one day and one satellite. Estimates of the flux at the TOA based on these measurements are also included.

Zenith
That point on the celestial sphere vertically above the observer.

19. List of Acronyms:

EOSDIS Acronyms.

ADM - Angular Distribution Model
ASDC - Atmospheric Science Data Center
AVHRR - Advanced Very High Resolution Radiometer
CERES - Clouds and Earth's Radiant Energy System (EOS-A)
DAAC - Distributed Active Archive Center
ERBE - Earth Radiation Budget Experiment
ERBS - Earth Radiation Budget Satellite
FOV - Field-of-View
GOES - Geostationary Operational Environmental Satellite
GSFC - Goddard Space Flight Center, Greenbelt Maryland, United States of America
HIRS - High-Resolution Infrared Radiometer Sounder
IBB - Internal Blackbody - used, in flight, to calibrate the ERBE sensors.
IPTS-68 - International Pressure and Temperature Standard of 1968
IMS - Information Management System
IVT - Instrument Validation Tape
LaRC - Langley Research Center, Hampton Virginia, United States of America
LW - Longwave
MAM - Mirror attenuator mosaic
MFOV - Medium Field-of-View
MRBB - Master reference blackbody
NASA - National Aeronautics and Space Administration
NESDIS - National Environmental Satellite and Data Information Service
NOAA - National Oceanic and Atmospheric Administration
NOAA-9 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 9
NOAA-10 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 10
NORAD - North American Aerospace Defense Command
NSSDC - National Space Science Data Center
PAT - Processed Archival Tape
POCC - Payload Operation and Control Center
RAT - Raw Archival Tape
SAGE II - Stratospheric Aerosol and Gas Experiment II

SOCC - Satellite Operations and Control Center (NOAA)
SW - shortwave
SWICS - shortwave internal calibration source
TDRSS - Tracking and Data Relay Satellite System
TIROS - Television Infrared Radiometer Orbiting Satellite
TOA - Top-of-Atmosphere
TOT - total (as in total channel)
URL - Uniform Resource Locator
UT - Universal Time
WFOV - Wide Field-of-View
WRR - World Radiation Reference

20. Document Information:

Document Revision Date:
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Document Review Date:
...
Document ID:
...
Citation:
...
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